Understanding context: its emergence, transformation and role in tacit knowledge sharing

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Abstract

Organizations, especially those adapting to rapidly changing environments, face the challenge of being able to solve complex problems within highly constrained timeframes. Complex problem solving has been addressed by theories of bounded rationality. However, these theories focus on solving complex but structured problems, and thus, context and how it emerges and transforms is not a central issue. More recently, theories of the firm as a knowledge-creating entity have focused on how organizations solve complex unstructured problems. These theories suggest that context and contextualization are central elements in problem solving. Yet, no understanding of how context emerges and transforms emerges from these theories. The present paper focuses on the emergence and transformation of context in solving complex unstructured problems, attempts to remedy the shortcomings of the theories described above and investigates the nature of context. Concludes by explaining its role in tacit knowledge sharing.

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Introduction

Complex problem solving, knowledge creation and creative work are of importance to organizations involved in knowledge intensive industries, particularly in the high-tech sector where technologies, markets and competitors change rapidly and knowledge may become obsolete almost overnight. In such environments organizational capabilities for knowledge creation and rapid execution of business strategies become a critical competitive advantage as unstructured and complex problems, that is problems for which the solution space is open ended, must be solved within highly constrained timeframes.

When people solve complex unstructured problems they bring knowledge and experience to the situation and as they interact during the process of problem solving they create, use and share knowledge. We claim that knowing how context emerges and transforms is of paramount significance if we want to understand how people create, use and share knowledge. We build this claim on the assumption that during problem solving people develop and modify their inter-subjective understandings, and as a consequence of these processes context emerges and transforms. In turn context influences what knowledge people choose to create, use and share, and thus, context influences what problems can be solved and how problems are solved.

The more exact processes by which context emerges and transforms are poorly understood. Thus, to make context and its emergence and transformation intelligible the paper focuses on the three questions:

(1) What is context?
(2) How does context emerge and transform?
(3) What is the relationship between context and the sharing of tacit knowledge?

Attempting to answer these three questions, the paper proceeds in the following way. Initially it describes how complex problem solving is conceptualized in theories of

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Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

bounded rationality and theories of the firm as a knowledge-creating entity. The paper argues that these theories either ignore context or lack detailed accounts for how context emerges and transforms. Thereafter, context is defined and, based on the theories developed by the Austrian sociologist, Alfred Schutz, a theory of how context emerges and transforms is put forward. This theory of context, its emergence and transformation is applied in interpreting a case on the Carbon Dioxide filtering problem occurring during the ill-fated *Apollo 13* mission. Finally, in closing, the paper describes how the proposed theory of context can help us to understand the role of context in tacit knowledge sharing.

Complexity in problem solving: some theories of bounded rationality

One attempt to formulate theories of complexity in problem solving comes from the fields of behavioral economics and psychology. Simon (1959) believed that psychology could add to economics the idea that choice depends not only on the "object" conditions, but also on the "internal nature" of the decision makers, and thus, he believed that psychology could contribute to the development of a more valid understanding of economic choice. Simon's belief in complexity formed the basis for his development of the concept of bounded rationality (Simon, 1976).

Theories of bounded rationality (Simon, 1976; 1978), including prospect theory (Kahneman and Tversky, 1979), suggest that when facing complex problems and trying to make reasonable (though not necessarily rational) decisions within highly constrained timeframes, humans reach the limits of their cognitive and information processing capabilities. Thus, to cope with the situation, they construct simplified models (rules of thumb and heuristics represent such models) in order to make up for their cognitive limitations. Heuristics "reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations" (Tversky and Kahneman, 1974, p. 1124). Thus, heuristics help problem solvers to economize with their limited cognitive resources, and thereby, to engage in complex problem solving. However, heuristics also introduce errors and biases. Among these errors are the insensitivity to prior probabilities. That is, people rely on representativeness, rather than statistical implications of the probability distribution of an event, because they cannot foresee all possible future contingencies. This makes them act insensitively to issues of predictability. We try, and fail – make mistakes – in a constant attempt to solve complex problems:

> The world will always remain the largest laboratory, the largest information store... Of course it is costly to learn from experience, but it is also costly, and frequently much less reliable, to try through research and analysis to anticipate experience (Simon, 1971, p. 47).

Thus, Simon posits that decision makers must find ways to act reasonably within the limitations of their mental resources. The concept of "bounded rationality" captures the idea that the cognitive limitations of human decision makers should be added to the host of other limitations on the decisions.

Limitations of the theories of bounded rationality

Economists have argued that Simon focuses too much on the difficulties in finding the optimal solution within a complex but in principle already structured system. The boundary to rationality becomes merely a reflection of people's computational abilities (see Langlois, 1997, p. 12). For Simon, humans face no difficulties in grasping the structure of the problem situation; instead difficulties are due to finding the optimal solution (Langlois, 1984; 1990). What is bounded, then, is essentially not "rationality" *per se*, but the ability to solve the problem – the "computational ability" (Langlois, 1984; 1990). Perhaps Simon's preoccupation with chess and computers reveals a bias, as they seem to blame the boundaries to rationality solely on the actors. Indeed, it could also be blamed on the problems being too unstructured and complex to comprehend. As a result, theories of bounded rationality do not address the issue of context.

In spite of the critique it is without doubt that theories of bounded rationality represent important attempts to deal with real world complex human problem solving. But models of structured problems, like the towers of Hanoi, are of limited value because they reinforce the assumption that problems can be solved without paying attention to context.

We believe that unstructured and complex problems are created, shaped and solved in the process of choosing, and that it is in this process that context emerges and transforms. Consequently, we claim that problem solving depends both on the problem solvers, the environment in which they exist and the emerging context in which problems become situated. Accordingly we claim that Simon's approach to complex problem solving pays too little attention to how context influences complex problem solving, and how context emerges and transforms during the problem solving process.

Complexity in problem solving: theories of the firm as a knowledge-creating entity

A second attempt to formulate theories of complexity in problem solving comes from the field of knowledge management. Within this field scholars have recently proposed a knowledge-based view of the firm. The knowledge-based view of the firm attempts to remedy what is perceived as the shortcomings of existing theories of the firm. These theories (complexity economics, transaction-costs theory, principal-agent theory) "are based on the assumption of bounded rationality" (Nonaka *et al.*, 2000a, p. 2) and because they regard humans as isolated static beings, these theories are "crucially limited in explaining the firm as a knowledge-creating entity" (Nonaka *et al.*, 2000a, p. 3).

The knowledge-based view of the firm perceives organizations as knowledge-creating entities, and it suggests that organizational capabilities to create and utilize knowledge are the most important sources of competitive advantage (Cyert *et al.*, 1993; Kogut and Zander, 1996; Nonaka, 1994; Nonaka *et al.*, 2000a; Prahalad and Hamel, 1990; Winter, 1987). Nonaka *et al.* (2000a, p. 1) note:

> Knowledge and skills give a firm competitive advantage because it is through this set of knowledge and skills that a firm is able to innovate new products/processes/services, or improve existing ones more efficiently and/or effectively.

In Nonaka's (1994) version of the theory, knowledge is defined as justified true belief, emphasizing the justified more than the true aspect of belief. According to Nonaka (1994) knowledge is created through knowledge conversion[1], that is, "through interactions between tacit and explicit knowledge, rather than from tacit or explicit knowledge alone" (Nonaka *et al.*, 2000b, p. 8). Furthermore, it is suggested that "knowledge is created through the dynamic interactions among individuals and/or between individuals and their environments" (Nonaka *et al.*, 2000a, p. 3) rather than by an individual operating alone in a vacuum. Hence, it is emphasized that knowledge creation is a collective activity. The organization, it is said, "creates and defines problems, ... and generates new knowledge through the action of problem solving (Cyert and March, 1963; March, 1991; Nonaka *et al.*, 2000a, p. 3).

Typically the problems solved are both unstructured and complex, and knowledge creation is "inherently a highly uncertain activity. The technical and commercial outcome of research activities can hardly be known *ex ante* (Dosi, 1988). It is difficult to know in advance not only the precise cost and outcomes of different alternatives but also what the alternatives are (Nelson and Winter, 1982)" (Nonaka *et al.*, 2000a, pp. 4-5).

Nonaka *et al.* (2000a, p. 8) suggest that the firm can be conceptualized as a dynamic configuration of 'ba' (roughly means place). "Ba" is defined as the context shared by those who interact with each other, and "ba" is the place where they create, share and use knowledge. Through the interaction in "ba" the participants in "ba" "and the context itself evolve through self-transcendence to create knowledge. In other words, "ba" is an emerging relationship among individuals, and between an individual and the environment" (Nonaka *et al.*, 2000a, p. 9). In addition, Nonaka *et al.* (2000a, p. 9) note:

> "Ba" lets participants share time and space, and yet it transcends time and space. In knowledge creation, it is important for participants to share time and space, as such a close, physical interaction is an important factor to sharing the context and forming a common language among participants.

Putting knowledge in context is important, Nonaka *et al.* (2000a, p. 8) argue, because "knowledge creating processes are necessarily context-specific, in terms of who participates and how they participate in the process. The context here does not mean 'a fixed set of surrounding conditions but a wider dynamical process of which the cognition of an individual is only a part' (Hutchins, 1995, p. xiii). Hence knowledge needs a physical

Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

context to be created, as 'there is no creation without place' (Casey, 1997, p. 160)." In "ba" "new knowledge is created out of existing knowledge through the change of meanings and the contexts" (Nonaka *et al.*, 2000a, p. 8).

Limitations to the theories of the firm as a knowledge-creating entity

The initial step towards a theory of the firm as a knowledge-creating entity (Nonaka *et al.*, 2000a) has given some insights to knowledge-creation in organizations. In addition, with the introduction of the concept of "ba", a step towards a conception of context has been taken. However, it remains unclear what exactly "ba" is, how does "ba" emerge, and what exactly happens inside "ba".

The definition of "ba", offered by Nonaka *et al.* (2000a), is unclear or ambiguous at best. On the one hand they note, that "knowledge needs a physical context to be created, as 'there is no creation without place'" (2000a, p. 8). On the other hand they note that "'Ba' does not necessarily mean a physical space. Rather, it is a specific time and space" (2000a, p. 9). Furthermore, "ba" seems to be a very inclusive concept. According to Nonaka and Konno (1998, p. 40) "'ba' can be thought of as a shared space for emerging relationships. This space can be physical (e.g. office, dispersed business space), virtual (e.g. e-mail, teleconference), mental (e.g. shared experiences, ideas, ideals), or any combination of them". Therefore, we think it is fair to ask: What is not included in "ba"?

Concerning the emergence of "ba" then it seems that on the one hand "ba" is created spontaneously. "'Ba' is constantly in motion. 'Ba' is fluid, and can be born and disappear quickly. In organization knowledge creation, various 'ba' interact with each other to evolve into a higher self" (Nonaka *et al.*, 2000a, p. 9). On the other hand "ba" can be built intentionally (Nonaka *et al.*, 2000b). Nonaka *et al.* (2000a, p. 12): "...building 'ba' such as project teams or functional departments, and determining how such 'ba' should be connected to each other, is an important factor in determining the firm's knowledge creation rate." Finally, it is noteworthy that "the boundary for 'ba' is fluid and can be changed quickly as it is set by the participants. Instead of being constrained by history, 'ba' has a 'here and now' quality. It is constantly moving; it is created, functions and disappears according to need" (Nonaka *et al.*, 2000b, pp. 15-16).

Regarding the question: What exactly happens inside 'ba'? Then it seems that the closest we get to an answer to this question is provided by Nonaka and Toyama (2000, p. 3) who write:

> ..."ba" is... an open space where participants with their own contexts can come and go and the shared context (i.e. "ba") can continuously develop.

Thus, although the concept of "ba" (Nonaka and Konno, 1998; Nonaka *et al.*, 2000a) represents an attempt to define context, we are still far from an explanation of how context emerges and transforms, and thus, we have yet to understand what happens inside "ba", and what it is that makes "ba" such an excellent place for knowledge creation. It seems that the concept of "ba" attempts to capture everything and thus it ends up capturing nothing. Therefore, we find that there is a need for further development of the concept of "ba", e.g. in a synthesis with research in the field of cognitive science.

The problem of understanding context

The examination of existing theories concerned with complex problem solving as well as knowledge creation showed that none of them accounts for the emergence and transformation of context. Also, it demonstrated that none of them provides an in-depth understanding of what context is. Therefore, we maintain that there is a need for explaining both context and its emergence and transformation – especially, since this need for understanding context is urgent when the problems to be solved are complex and unstructured. For such problems the solution space is open ended, that is, no optimal solution exists a priori, and problems are "shaped" as they are solved.

We suggest that contexts are not "just there" as static entities; instead contexts are emergent phenomena. The same idea has been put forward by Erickson and Schultz (1997). They describe context as a mutually constituted, constantly shifting, situation definition that emerges through the interaction of the involved individuals. "Contexts are not simply given in the physical setting ... nor in combinations of personnel.... Rather, contexts are constituted

Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

by what people [do and where and when they do it]. As McDermott puts it succinctly (1976), 'people in interaction become environments for each other'" (Erickson and Schultz, 1997, p. 22). And Dilley agrees (1999, p. 19): "Context is both constitutive of social action and itself the outcome of social action, it is both a generative principle and a resulting outcome."

In neither of these two quotations is it clear if context is perceived to be an individual or a collective construct. We suggest that context is an individual construct. Our outset for this suggestion is Polanyi's (1962) statement that all knowledge is personal knowledge. Additionally, we suggest that context emerges as an individual encounters a situation, including others and artifacts, as it is the individual's interpretation of a situation that results in context. After its emergence the context transforms as the situation evolves, for example, as a result of the action of the individual and the others being involved.

As we claim it is the individual interpretation of a situation that results in a context, we imply that the context emerging for an individual in a specific situation, is based on what that individual experienced in prior times. Thus, as two individuals never hold similar experiences the contexts emerging for two individuals will never be similar. Yet, similarities among individual experiences might result in contexts with many similarities. Another important implication of our context definition is that if individual X encounters situation Y in both t=1 and t=2, then the contexts emerging for individual X at these two points in time will differ as individual X brings different experiences to the two instances of situation Y. Hence, with our definition of context as an emergent and individualistic construct we are in agreement with Rapport (1999, p. 190):

> Context is determined by the questions which people ask of events... Just as many questions can be asked of events, so there will be many contexts; just as different people can ask different questions of events, so different people will determine different contexts; just as people can ask a number of different questions of events at the same time, questions of which other people may or may not be aware, so different people can simultaneously create and inhabit multiple contexts, contexts whose commonality is questionable.

Assuming that the questions individuals ask of events are determined by their experience, then there can be little doubt that contexts emerge and transform during acts of interpretations. Yet, so far we have only presented preliminary thoughts about these acts of interpretations. Therefore, we address this issue below, using the theories of Schutz (1962; 1964a; 1967) on inter-subjectivity, typicality and ideal types.

Inter-subjectivity, typicality, ideal types and context

We choose Schutz as our main source since one of his major focuses was on how cooperation evolves among actors who are more or less anonymous to each other (Ebeling, 1987). Because of Schutz's (1962; 1964a; 1967) interests in explaining human action he offers deeper insights into context. Schutz explains (Augier, 1999, pp. 158-9):

> ... that our "life world" consists of a multitude of others, with whom we live and interact, although our knowledge about them is scarce. That is, we are more or less 'anonyme' to each other, despite the fact that the life world in which we are both is full of structures containing inter-subjective knowledge (see Schutz and Luckmann, 1973; 1989). This knowledge is used by imputing "typical" "course of action-types" and "personal ideal types" to the individuals to analyze what happen if he/she follow particular "roles" (personal ideal types) or pursue certain ends ("course of action-type").
>
> Ideal types are used when we act and interpret events in the social world and ideal types are abstractions from the particulars and the idiosyncrasies of the world, and thus, they produce statements of general validity. Hence, we know some part of the world precisely because of its character as ideal typical knowledge. Ideal types can be "... arranged according to the degree of increasing anonymity of the relationship among contemporaries involved and therewith of the context needed to grasp the other and his behavior. It becomes apparent that an increase in anonymity involves a decrease in fullness of content. The more anonymous the [ideal type] is the more detached is it from the uniqueness of [other individuals involved],... If we distinguish between (subjective) personal ideal types and (objective) course-of-action types we may say that increasing [anonymity] of the construct leads to the superceding of the former by the latter" (Schutz, 1962, p. 17-18).

In addition to our ideal typical knowledge we possess more specialized information about particular kinds and groups of others, of their motivations and actions. If we formerly had

Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

direct experience of the particular other facing us now, we can fall back on the specialized information extracted in these experiences (Schutz, 1964a, p. 30).

The individual brings ideal typical knowledge and more specialized information about others, artifacts and situations, to a situation. Here they constitute the basis for the individual's interpretation of the situation, including others and artifacts, and thereby for the individual's conception of context. Consequently, specialized information and ideal types are the basic elements from which context emerges.

Others whom we encounter in the social world do not appear to us in identical perspectives. They present themselves to us under different aspects and our relations with them have different degrees of intimacy and anonymity (Schutz, 1964a, p. 22). It is possible to distinguish among three types of relations; *they relations*, *thou relations* and *we relations* (Schutz, 1967). In we relations individuals are aware of each other and of the awareness, and they are able to obtain understanding of each other's motives. In thou relations no such reciprocal awareness exists and understanding involves more anonymous types of meaning. Finally, in they relations individuals use ideal types in order to impute "typical" motives into each other and thereby understand each other's actions.

In we relations we experience others directly, as we and they share a common sector of time and space. The sharing of a common sector of time implies that we and others age together. The sharing of a common sector of space implies that we and others appear to one another in person as ourselves and nobody else (Schutz, 1964a) "In the ongoing experiences of the we-relation I check and revise my previous knowledge about my partner and accumulate new [specialized] knowledge about him. Thereby my general stock of knowledge also undergoes a continuous modification" (Schutz, 1964a, p. 30). In we relations the sharing of experiences bestows upon the world its inter-subjective, social character. "It is not my environment nor your environment nor even the two added; it is an inter-subjective world within reach of our common experience" (Schutz, 1964a, p. 31).

In they relations our partners are not concrete and unique individuals, but types (Schutz, 1964a, p. 45), and "the experiences of contemporaries appear to [us] more or less anonymous processes" (Schutz, 1964a, p. 43). As a result we obtain relatively little specialized information about their motives and actions. Also, in they relations my experience of my contemporaries is not continuously modified and enriched.

> Each new experience of contemporaries adds, of course, to my stock of knowledge; and the ideal types by which I am oriented to others in a they relation do, indeed, undergo modifications .... But these modifications remain minimal as long as a given situation and my interests in it – which have determined the original application of a given typifying scheme – remain constant (Schutz, 1964a, p. 55).

The ideal typical knowledge and the more specialized information that we obtain in our relations with others enable us to interpret and give meaning to the behavior by others. However, these meanings may not correspond to the meanings of the others. Schutz (1967, p. 20):

> ... we must emphasize ... that the subjective meaning of another person's behavior need not to be identical with the meaning which his perceived external behavior has for ... an observer.

In we relations we can assign our meaning to others with greater confidence, as the world within their reach coincides with ours. In they relations this reciprocity of experiences is replaced by acts of reflection on the typifying scheme which presumably orients the conduct of both they and us. The validity of our assumption that they share a given typifying scheme with us cannot be verified, since they are not present (Schutz, 1964a, p. 54). "I cannot presuppose, for example, that my partner in a they relation will grasp a nuance of a word or that he will place a statement of mine in the proper context unless I explicitly and 'objectively' refer to that context. The direct evidence that I have been understood, which I have if my partner is present in the community of space and time, is lacking in a they relation" (Schutz, 1964a, pp. 55-6).

From the above it follows that individuals who have prior experience from a range of we relations with each other are likely to establish contexts with many similarities. In contrast, individuals who have little prior experience from we relations with each other are likely to establish contexts with few similarities. Therefore, as a group begins problem solving, the members of the group are not necessarily in the position to understand one another. Yet, as individuals we assume that everybody

Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

takes the world around us for granted in essentially the same way as we do ourselves, and thus, we orient our actions towards other people, assuming that they will behave in a "typical" manner. Consequently, it might take time before we register that this is not the case, and thereby, register that little common understanding has emerged.

People solving complex unstructured problems

We now present a case study to illustrate emergence and transformation of context. We have chosen a case where an unstructured problem is solved within a constrained timeframe, as we believe that it is during such problem solving processes that emergence and transformation of context are most visible. Concerning the applied problem solving technique we assume that the shorter the time horizon and the more unstructured the problem, the more likely people are to improvise. In a two-by-two matrix that characterizes problems according to the problem structure and time available for problem solving, improvisation represents one of the four responses to problem solving. The other three responses are analysis, simulation and heuristics (see Figure 1).

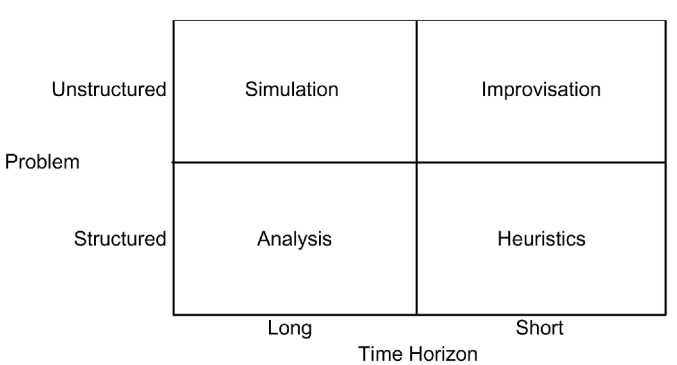
Recently it was suggested that "people improvise when they are overwhelmed by the world, and thus, is forced to read the world in a different way"[2]. In a follow up Louis (1980, p. 244) suggests that people feel overwhelmed by the world when their actual experience in a situation differs from their anticipation of that situation.

Improvisation is "the degree to which the composition and execution of an action converge in time" (Moorman and Miner, 1998, p. 698), and it is "a situated performance where thinking and action emerge simultaneously and on the spur of the moment. It is purposeful human behavior which seems to be ruled at the same time by intuition, competence, design and chance" (Ciborra, 1999, p. 78). Thus, it is the lack of time[3] to solve complex unstructured problems that leads people to improvise. Improvisation "involves reworking pre-composed material and designs in relation to unanticipated ideas conceived, shaped, and transformed under the special conditions of performance, thereby adding unique features to every creation" (Berliner, 1994; quoted from Weick, 1998, p. 544). Furthermore, improvisation is grounded in memory of the past (Weick, 1998, p. 547), and thus, improvisation is grounded in the ideal typical knowledge and more specialized information that individuals bring to the problem solving process. Yet, as improvisation happens when people are overwhelmed by the world and forced to read it in a different way, then the knowledge they immediately recall might not be relevant in the problem solving process. Because, in situations where people are overwhelmed by the world the relevance of knowledge is likely to change.

Writing about knowledge Schutz distinguishes among "four regions of decreasing relevance" to our knowledge (1964b, p. 124). First, there is the "zone of primary relevance" (1964b, p. 124), which can to some extent be changed and rearranged by our actions. For this part of the world we need know-how and relatively precise understandings of why, when and where to employ it. Second, there are regions closely "connected with the zone of primary relevance" (1964b, p. 124), but not subject to our control. Hence, they establish the conditions for our action. Third, there are the relatively irrelevant zones. They are taken "for granted as long as no changes occur within them which might influence the relevant sectors by novel unexpected changes or risks" (p. 125). Finally, there are the absolutely irrelevant zones of knowledge. "Because no possible change occurring within them would or so we believe influence our objective at hand" (p. 125).

Knowledge in the two inner zones of relevance governs action, whereas knowledge in the two outer zones cannot govern action until it moves to the inner zones of relevance.

Figure 1. Problem solving responses



Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

Knowledge may move between zones, and thereby its relevance changes. Knowledge moves between zones of relevance when it is discovered that it can be helpful for problem solving, or when its value diminishes due to changed conditions for problem solving.

Problem solving in the ill-fated Apollo 13 mission

The *Apollo 13* mission was going well when the message "Okay, Houston, we've got a problem here..." came from the *Apollo 13* Command Module. An oxygen tank had exploded, severely damaging the Service Module and leaving the Command Module without power or air. After a rapid assessment of the health of the spacecraft it was decided to abandon the mission, move the three astronauts into the Lunar Module, and attempt a loop around the moon in order to get the astronauts back to earth.

> Soon after the explosion, the assessment of life-support systems determined that although oxygen supplies were adequate, the system for removing Carbon Dioxide in the Lunar Module was not. The Lunar Module was designed to support two men for two days and was being asked to care for three men nearly four days. Thus, removal of Carbon Dioxide in the Lunar Module became a concern. The system in the Lunar Module used canisters filled with Lithium Hydroxide to absorb Carbon Dioxide as did the system in the Command Module. Unfortunately the canisters were not interchangeable between the two systems, so the astronauts were faced with plenty of capacity for removing Carbon Dioxide but no way of using it[4].

Facing this potentially fatal problem a team of ground crews at the NASA Mission Control in Houston brought into a room all the items available to the astronauts on board the spacecraft (see Plate 1). What they had at hand included the several items composing the space suits originally planned to be used by the astronauts during their visit to the moon. Using these items the team worked on a solution and constructed a device it believed would work and could be implemented by the astronauts. In order to test if the solution could be implemented on board the spacecraft, based on instructions given from the Manned Space Center, they placed the astronaut, who could not go on the *Apollo 13* mission for health reasons, in a spacecraft simulator, and gave him the instructions. After a few corrections the solution was verified in the simulator and the instructions were transmitted to the astronauts in the spacecraft. The astronauts succeeded in assembling the two carbon dioxide removal devices:

Plate 1 At NASA Mission Control in Houston's Manned Spacecraft Center, Donald K. "Deke" Slayton, left, director of flight crew operations, holds Lithium Hydroxide canisters attatched to a hose as he discusses a makeshift repair to reduce the dangerous levels of Carbon Dioxide abroad Apollo 13, April 15, 1970. Dr Robert Gilruth, director of MSC, holds the end of the hose at right, as launch director Kurt Debus, seated left, and deputy directory Christopher Kraft, also seated, look on. Man standing at center is unidentified

> There was, of course, a fix; and it came in the form of an ingenious combination of suit hoses, cardboard, plastic stowage bags, and Command Module canisters – all held together with a liberal application of gray duct tape. As was usual whenever the Apollo team had to improvise, engineers and astronauts on the ground got busy devising ways around the problem and then checked out the new procedures. A day and a half after the *Apollo 13* accident, the ground teams had designed and built a filtering device that worked to their satisfaction. They promptly radioed instructions to the crew, carefully leading them through about an hour's worth of steps. As Lovell wrote later: "the contraption wasn't very handsome, but it worked". And that was all that mattered[5].

Emergence and transformation of context in the Apollo 13 case

We draw inferences about the emergence and transformation of context in the *Apollo 13* case in three parts. First, we show how the need for problem solving by improvisation emerged, then we interpret how the ground crew responded to the need for problem solving and third we discuss the conditions for their

Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

success with improvisation as their problem solving method.

The need for problem solving by improvisation was triggered as the explosion happened on board the spacecraft, and forced the NASA Mission Control Team into action to save the life of the three astronauts. The team was immediately overwhelmed by the urgency of the crisis. However, the solution to the problem could not be found within the usual solution possibilities that were available on earth. The challenge was to create the solution that could be implemented by using the limited number of different items that were available on board the spacecraft. Hence, the knowledge usually employed by the ground crew in solving the Carbon Dioxide filtering problem was not sufficient to solve the problem. The ground crew had to move beyond their *ex ante* knowledge, and while improvising include and create knowledge relevant to them in the present problem solving situation. Hence, the process used by the team can be best characterized as creative destruction of knowledge. This, in essence, represents the process of improvisation, used by the ground crew to construct the device to solve the Carbon Dioxide filtering problem on board the spacecraft.

In our interpretation of how the ground crew responded to the need for improvisation we assume that as soon as the Carbon Dioxide filtering problem was known to the ground crew they all started producing their personal interpretation of what it meant and how it could be solved. We postulate that as a result context emerged for each of them, with their individual contexts including their knowledge about how each of the other ground crews could contribute to the problem solving – this knowledge being based both on ideal types of these others and on more intimate experiences from past we relations with them.

Realizing that the solution to the Carbon Dioxide filtering problem could not be found within the usual solution space, the ground crews experienced that parts of their knowledge about Carbon Dioxide filtering problems were not relevant in the present problem situation. As the relevance of this knowledge diminished they experienced the first transformation of their contexts. Then faced with the fact that the solution had to be constructed from the items available to the astronauts on board the spacecraft, and thereby, becoming aware of the actual solution space for the Carbon Dioxide filtering problem, the ground crew experienced yet another transformation of their contexts, as now they had to perceive their knowledge about the Carbon Dioxide filtering problem within the permutations of possibilities that were likely within the scope of items that were available on board the spacecraft. By perceiving and acknowledging this as a relevant constraint they adapted their contexts to the complexity of the problem situation. Also, we assume that when adapting their contexts they took into account what they knew about other team members' knowledge and experience with the Carbon Dioxide filtering problem and the possibility of applying this knowledge within the limitations posed by the available items on board the spacecraft. Consequently, they experienced that knowledge previously perceived to be irrelevant to the Carbon Dioxide filtering problem might be relevant in this particular situation, and thus, within a very short timeframe contexts emerged and were transformed twice.

Reviewing the process of solving the Carbon Dioxide filtering problem we suggest that the ground crew experienced that none of them held sufficient knowledge to solve the problem on their own. Hence, they realized that collaborative problem solving was needed and that knowledge sharing was necessary for creating a solution. It is our assertion that knowledge sharing required that the problem solvers took on thou orientations towards each other. Thereby, they established we relations in the problem solving process, as otherwise they could not obtain verifications of similarities in typifying schemes among themselves and their partners, and would not have been able to solve the problem.

Nevertheless, establishment of we relations in problem solving is not sufficient to give way for effective knowledge sharing and improvisation. Also, attention needs to be paid to the intimacy of we relations, that is, how easy problem solvers experience it is to follow each other's lines of thoughts. We suggest that the intimacy of we relations is a result of the extent to which the context emerging and transforming for each of the problem solvers exhibits similarities with the contexts emerging and transforming for the other problem solvers. In turn the emergence of contexts with many similarities requires

Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

that problem solvers have shared many common sectors of time and space prior to the problem solving *in situ*. Consequently, the less anonymous problem solvers are to each other, the fewer obstacles to knowledge sharing and improvisation they will experience. In fact, these preconditions existed in the *Apollo 13* case where the ground crew as well as the astronauts held similar experiences from prior training and collaboration. Had this prior sharing of common sectors of space and time not existed, we assert that the ground crew would have experienced difficulties in following each other's line of thought and in gaining a common ground for problem solving by improvisation. Because then larger variations among contexts would have existed and as a consequence they would not have been able to solve the Carbon Dioxide filtering problem quickly.

In conclusion, we find that successful problem solving in the *Apollo 13* case was conditioned on: first, the ability of the ground crew to register the world and form novel views of the available resources (the suit hoses, cardboard, plastic bags, tape, etc.) as possible components of a Carbon Dioxide filtering device; and, second, the establishment of we relations, which allowed for the emergence of contexts with many similarities and thereby for knowledge sharing.

Accordingly, it is not necessarily experience with improvisation that enables people to solve complex unstructured problems within constrained timeframes. Instead, it is the ability to create contexts with many similarities as well as the possession of in-depth, and perhaps irrelevant, knowledge about the items available for the creation of a solution.

In closing: context as sharing of tacit knowledge

In the introduction we posed three salient questions:

(1) What is context?
(2) How does context emerge and transform?
(3) What is the relationship between context and the sharing of tacit knowledge?

Using Polanyi (1962) as our point of departure we argued that context is an individual construct. Furthermore, we suggested that context emerges as an individual encounters a situation. Consequently, contexts are not "just there" as static entities.

Thereafter, by using the theories of Schutz (1962; 1964a; 1967), we suggested that it is the individual interpretation of a situation, including others and artifacts, that result in the emergence of a context. We suggested and showed that interpretation happens as individuals bring their experience in the form of their ideal typical knowledge and more specialized information to the situation. Subsequently, their contexts transform over time, as they are confronted with other problem solvers and constraints imposed on the problem solving process. Hence, our findings are in agreement with the results of Zhang and Norman's (Zhang, 1997; 1998; Zhang and Norman, 1994) study of distributed representations (internal and external) in problem solving by groups. They arrived at a general principle regarding representations similar to the one we arrived at regarding contexts. Zhang (1998, p. 809): "representations of a group problem solving task is distributed across individual representations, which jointly represent the abstract structure of task."

In response to the third question we argued that tacit knowledge sharing in solving complex unstructured problems requires the emergence and maintenance of contexts with many similarities, as otherwise problem solvers cannot obtain verifications of similarities in understanding, e.g. of knowledge and problems. Furthermore, we have argued that contexts with many similarities can only emerge if problem solvers have shared many common sectors of time and space prior to the problem solving *in situ*. Consequently, tacit knowledge sharing in solving complex unstructured problems will not take place if not being prepared for.

We suggest that there are many reasons to pay attention to context, its emergence and transformation. Foremost, as the complex technologies of today are the source of novel and incomprehensible problems, people depend heavily on their interpretation of what might have happened. But they can never be sure, as complex technology admits several equally plausible and possible interpretations, and thus, they are subject to misunderstandings (Weick, 1990). In such situations problem recognition and diagnosis are wholly dependent on human processing

Journal of Knowledge Management
Volume 5 · Number 2 · 2001 · 125–136

and on whatever models and experience the operator brings to the task of problem solving (Weick, 1990, p. 15). Hence, understanding how context emerges and transforms, and the role of context in tacit knowledge sharing can provide important clues for how to design organization for management of complex technologies.

Finally, the salience of context is becoming increasingly apparent to decision makers as they face compressed timeframes for decision making while at the same time the complexity of problems they face requires bringing together knowledge from experts in many specialized domains. We envision that the ability to understand the emergence and transformation of context, and the relationship between context and the sharing of tacit knowledge, is of strategic importance to the success of organizations as they face the pace and the acceleration of operations in the knowledge based economy.

Notes

1 Four modes of knowledge conversion exist; socialization, externatlization, combination, and internalization (Nonaka, 1994).
2 From talk given by Claudio Ciborra at the Academy of Management Meetings in Toronto 2000.
3 This said so, although Ciborra (1999, p. 79) argues that "the effective improviser never seems to be worried by (a lack of) time; she just acts at the appropriate time".
4 http://www.hq.nasa.gov/office/pao/history/apollo/apo13hist.html
5 http://www.hq.nasa.gov/office/pao/history/alsj/a13/a13.summary.html

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